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Technical Report No. 10

A METHODOLOGICAL STUDY OF ELECTRONICS TROUBLE SHOOTING SKILL:

II. INTERCOMPARISONS OF THE MASTS TEST, A JOB SAMPLE TEST, AND TEN REFERENCE TESTS ADMINISTERED TO FLEET ELECTRONICS TECHNICIANS

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The publication of this report has been unavoidably delayed. The research described was accomplished in August 1953.

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PREFACE

This report is the tenth in a series published by the Electronics Personnel Research group. The first seven described shipboard observation of electronics personnel aboard ships of the destroyer class. The eighth, ninth, and tenth reports are concerned with the results of collateral research.

The ninth report describes a new type of test format, the MASTS test, designed for measuring some aspects of trouble shooting skill, and sets forth the conception of trouble shooting underlying its development.

This report contains a summary of the results of a preliminary study in which the MASTS test, a job-sample test, three conventional electronics tests, and several ability reference tests were administered to a small sample of Electronics Technicians from ships undergoing repairs in the Long Beach Naval Shipyard.

The study yielded positive results insofar as the experimental instrument was concerned. However, it had two characteristics which precluded its economical use on large samples: it was an individual test and it required an observer to record each subject's presolution responses. In view of the fact that the preliminary results were promising, an immediate revision of the MASTS tests was begun; and currently is in progress, to convert the instrument from an individual to a group test, and to provide a mechanism for automatically recording the subject's successive responses. Because of this self-recording feature, the name AUTOMASTS is being applied to the revision.

In the interests of economy, it has been necessary for the project to concentrate its efforts on the AUTOMASTS. Therefore, Technical Report No. 10 must be considered as an interim report covering a portion of the performance records which were collected at Long Beach. Specifically, the report contains only end-product scores, so far as the MASTS test and the job-sample test are concerned. The detailed records which were taken of the subjects' presolution responses are being used in conjunction with the development of new scoring parameters for the revised test, and will be discussed in the reports concerned with that instrument.

ACKNOWLEDGMENTS

The research reported in this series reflects the contribution of a large number of persons within the Military Establishment. Grateful appreciation for this assistance is extended to the Cruiser Destroyer Force, Pacific; the Training Division and the Personnel Analysis Division, Bureau of Naval Personnel; the Personnel and Training Branch of the Psychological Services Division of the Office of Naval Research; and the Electronics Coordinator's Section of the Office of the Chief of Naval Operations.

The cooperation of the Commanding Officer, and of Mr. J. Wesley Johnson, Superintendent of Training, Long Beach Naval Shipyard, in permitting field work to be done there, and in providing testing space, is especially appreciated.

Mr. William Hickman, Training Division, Long Beach Naval Shipyard, devoted many hours of his own time to orienting two of the project personnel in electronics and in acting as a technical consultant. His contribution is gratefully acknowledged.

The non-electronic reference tests were obtained through the courtesy of Dr. J. P. Guilford and Mr. P. R. Christensen of the High-Level Aptitudes Research Project, Contract N6onr-238-10, University of Southern California.

Mr. John R. Hills, half-time research assistant, contributed materially to the collection of problem information and to the planning of the new test format. Harold R. LaPorte and Donald W. Svenson served at different times as liaison men between ship personnel, the testing room, and the Electronics Personnel Research Offices.

ABSTRACT

This report summarizes the results of an exploratory use of the MASTS test with Electronics Technicians. This test, a job-sample test, and several electronics and ability reference tests were administered to a small sample of ETs. Rank order correlations of end-product scores, between the MASTS test and its job-sample counterpart, were positive and significant. The report describes the tests involved in the study, the subject sample, and the procedures followed.

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I. INTRODUCTION

The study to be described is part of a general program to analyze objectively and to describe the job of the naval electronics technician. Some studies in the program have been concerned with the observation of maintenance problems in the fleet (Reports 1 through 7 of this series), while others have concentrated on the analysis of the behavioral aspects of electronics trouble shooting. Following a logical analysis of the trouble shooting process, a job-sample test requiring the repair of standardized equipment was developed, along with a symbolic version of the tasks involved. The latter was put into a special test format called the MASTS test, (see Report 9 of this series). The study reported here gives the results of an exploratory administration of several measures of trouble shooting skill to a group of experienced electronics technicians in the fleet.

The study had three specific objectives:

1. The first was to evaluate the feasibility of a trouble shooting performance test more symbolic in nature than an equipment test (or performance on the job), yet not as restrictive as conventional paper-and-pencil tests. Such an instrument (the MASTS test) was evaluated by comparing it with an equipment test in terms of end-product scores.

2. The second goal involved collecting empirical information from which revision and improved development of such a test could be achieved, if the instrument proved feasible.

3. The third objective was to explore the relationships among the two performance tests (job-sample and MASTS) and selected reference variables. The reference measures were of three main classes: paper-and-pencil electronics tests, ability reference tests, and supervisor's ratings.

II. DESCRIPTION OF MATERIALS AND SUBJECTS

Fourteen measurements, exclusive of part scores, were made for each of 36 electronics technicians. The measurements consisted of one job-sample trouble shooting test, two forms of the MASTS test (Plate 1), three electronics reference tests, seven ability reference tests, and one supervisor's rating. Each of the tests and the subject sample is described below.

A. The Job Sample Test (JS)

A performance test which closely resembled the trouble shooting of fleet electronics equipment was constructed from the circuit training racks and chassis developed by Philco. This gear had interchangeable chassis corresponding to circuit stages. With the exception of large transformers and some potentiometers, components were mounted on removable strips. This made replacement of components easy and facilitated introducing test problems (malfunctions) into the instrument (see Plate 2.)

Two separate racks were employed for the test. The chassis for a conventional superheterodyne receiver were assembled on one rack. The other rack contained a simplified sweep generator comparable to that used in radar circuits. As a result of preliminary testing, two sets of problems in the form of malfunctions (faults) introduced into the equipment were selected. These were used for alternate tests, each having six receiver and six radar problems. The problems were carefully selected and matched according to characteristic component failures of particular circuits or stages.

Auxiliary equipment for the job-sample test included a multimeter, signal generator, tube tester, cathode ray oscillograph, a set of hand tools, a rack containing spare parts, and a list of component values and circuit voltages. Each subject was introduced to the gear by a description of its general physical layout. He was given an opportunity to observe the equipment in normal operating condition and to study the schematic diagrams. This was followed by a warm-up problem to further orient the subject and to answer his introductory questions. For each subsequent problem the man was given general output symptoms only, such as might be reported by an operator calling for an ET.

By means of a special code a detailed account of the step by step responses of each technician was made as he used test equipment at test points and applied other diagnostic procedures to the equipment. Initial scoring was done in terms of the total number of problems solved and the median solution time per problem. Each problem was considered solved when the gear was put back in normal operation. A time limit of 35 minutes per problem was used in the job-sample test.

B. The Multiple Alternative Symbolic Trouble Shooting Test (MASTS)

This test replaced both electronic equipment and test instruments in the trouble shooting situation, by a symbolic format which contained a majority of the subtasks represented in trouble shooting behavior. For each problem, the subject was provided with a pool of information, which he could sample according to his own inclinations.

The apparatus and procedure for the MASTS test were described and illustrated in detail in Report 9 of this series. In brief, it consisted of a masonite board containing a matrix of holes, each provided with a removable cork. (Plate 1). When a cork was removed, a unit of the information typed on a problem sheet beneath the board was made visible. One hundred groups of five holes each were used to represent information on 100 different test points within the circuit in question. Five classes of information, AC volts, DC volts, ohms, signal generator readings, or wave forms, and the effect of "tapping" a test point with a screwdriver were included in the problem sheets.

In addition to the section containing information at test points, there was a panel containing holes for each component in the circuit, including major leads. The first column provided information which would be obtained from varying front panel controls and screwdriver adjustments. Six other columns were labeled "substitute new component." For any particular problem, one of the corks in this section corresponded to the component in the circuit which caused the malfunction. Under it was printed the phrase "gear normal." The spaces under the other corks in this section were blank.

The MASTS test contained twelve receiver problems and twelve radar problems. These were divided into two groups to provide two sets of problems, either of which could be used as one test. These tests were administered individually according to a standard procedure which was described in detail in Report 9. A time limit of 20 minutes per problem was used. The following performance records were obtained from each subject: (a) time required to solve each problem, (b) number of problems solved, and (c) complete response records of pre-solution behavior.

C. The Modified MASTS Test

A variation of the MASTS test was introduced to study the effect of making the discrimination of "usual" or "unusual" for each unit of test point information available to the subject. It was identical with the MASTS test except that all the readings were expressed in words which related the particular reading from faulty gear to the corresponding reading taken when the gear was functioning normally.

For example, when a man lifted a particular cork to obtain a DC voltage reading, instead of seeing a number he saw one of the following words or phrases: "up to infinity," "extremely high," "somewhat high," "usual," "somewhat low," "extremely low," or "absent." The word "usual" meant that the reading at this particular point was the same as it would be if there were no fault in the gear.

D. Reference Tests: Paper-and-Pencil Trouble Shooting Measures

Three paper-and-pencil tests of trouble shooting were constructed and administered as part of the test battery. The three tests differed systematically in degree of abstraction from the actual trouble shooting task. The first (ER-1) was a multiple-choice test of theory and electronics knowledge, particularly of how radio receiver and radar circuits operate. The second (ER-2) was a multiple-choice test of general trouble shooting in which generalized faults or malfunctions were related to possible causes.

The items of the third paper-and-pencil test (ER-3) were based on the same circuits used in, and on problems similar to the trouble shooting problems in the job-sample and MASTS formats. It presented these problems in terms of the conventional multiple-choice and other short answer type of item. A verbal statement of symptoms was made, followed by alternate statements about test points, relevant circuit tests, or likely faulty components.

E. Reference Tests: Ability Measures

A series of additional ability measures were introduced in an attempt to add meaning to any relationships determined among the performance variables. These ability tests were chosen from published tests on which standardization information was available. Particular attention was paid to the likely relevance of their factorial content to performance variables in the trouble shooting realm.

Two of the tests were from the Guilford-Zimmerman Aptitude Survey, Part I, Verbal Comprehension, and Part VI, Spatial Visualization. All others were special tests developed in connection with Naval studies of reasoning and flexibility of set. They included: the U.S. Navy Reasoning Test I; Problem Solving, Form AX2; Logical Reasoning, RL.R05A; Circle Reasoning (no code); Match Problems CX03B; and Brick Uses CF04A.

These particular tests were chosen because the abilities which they measure were hypothesized to be related to the skills required in trouble shooting electronics gear. The first two concerned comprehension of verbal materials and the ability to visualize spatial relationships, which were believed to play a part in electronics repair. A second group of tests sampled reasoning and problem solving abilities. The last two sets explored the element of flexibility of behavior, some aspects of which (e.g., functional fixedness) have been shown to be relevant to lack of success in problem solving behavior.

F. Subjects

The measures described above were administered to thirty-six experienced ETs obtained from ten ships in the Pacific Fleet (8 destroyers, 1 cruiser, 1 carrier). The services of these men were made available while the ships were in the Long Beach Naval Shipyard for repair. Facilities for testing were provided through cooperation of the Training Division of the shipyard.

In selecting subjects for testing, two criteria other than availability were used. No strikers were included who had not attended Class A electronics school; and, chiefs were not included because of the possibility that they may have become primarily supervisors. A detailed account of the ET sample by classes of ship, rate, length of experience as ETs, and extent of formal electronics schooling is given in Tables A and B in the appendix to this report.

III. THE EXPERIMENTAL DESIGN

Because of the fact that the principal measures in the group, the job-sample and MASTS tests, had not been used extensively before, it was not possible to predict the effect of certain test administration variables such as the order of administration of the tests, the order of problems within the tests, and the differences between problem groups.

It was therefore necessary to choose between two somewhat opposed goals for the observational situation: (1) to maintain the above conditions at as constant a value as possible in an attempt to keep correlations among the variables as high as possible; or (2) to systematically vary the conditions which appeared relevant in order that the extent to which they would affect test results could be objectively assessed.

In evaluating these alternatives it was recognized that the former would maximize the intercorrelations among variables unless some unfortunate selection of the "constant" values was chosen. On the other hand, this approach would yield no objective data on the effects of these variables which could be utilized in further work with the instruments.

The second alternative possesses almost opposite advantages and disadvantages. By systematically varying the test administration variables, one could objectively evaluate their influence, but correlations would be attenuated if these variables influenced scores.

Because the study was considered to be primarily an exploratory one, the decision was made to adopt a compromise solution. A counterbalanced design was developed which systematically varied (1) the order of administration of the job-sample and MASTS tests, (2) the order of the problems within the test, and (3) the assignment of problem groups (equivalence of problems). The design is diagrammed in Table C of the appendix. Twenty-four subjects were required for one administration without replication. Because the complete administration in counterbalanced order requires a very long testing time per subject, only one replication of the design (24 subjects) was used. To this was added a group of 12 subjects for whom all conditions were kept as uniform as possible.

These 12 subjects duplicated the conditions of 6 of the "counterbalanced" subjects, resulting in a "homogeneous" group of 18 subjects.

In summary, then, the compromise program of the research was to administer to 24 subjects one replication of the counterbalanced design described in Table C of the appendix, and to use a homogeneous set of conditions for an additional sample of 12 subjects. The set of values of the "controlled" variables used for the "homogeneous" group corresponds to the top row of the counterbalanced design (job-sample test first; problem order A, B, C, D, E, F etc.). Subsequent analyses will be made in terms of the total group (36 men), the homogeneous sub-group (18 men), and the counterbalanced (heterogeneous) sub-groups (24 men).

IV. RESULTS

A. Comparison of the MASTS Tests With the Job Sample Test

1. The MASTS Test. On the assumption that the symbolic (MASTS) test measures many of the same skills that the job-sample test does, a significant correlation would be expected between scores on the two measures. Two classes of scores could be used for studying this relationship: one based on gross performance (such as number of problems solved and time required for solution), the other based on analysis of intermediate response records. Only the first of these will be discussed in this report.

Several types of gross scores are available. The two most obvious are: (a) the number of problems solved within the problem time limit, and (b) some average (median) of the solution times of the subject per test.

The scores were first arranged in order according to the number of problems solved. Then, since there were several persons with the same number of solutions, the median solution times were introduced as a basis for differentiating among these "ties." For these combination measures, the rank order correlations between job-sample and MASTS total scores for different subject and problem groups are given in Table I. Similar correlations for part scores are indicated in Table II for the total group (N = 36); for the homogeneous group (N = 18); and for the counterbalanced group (N = 24).

Table I

Rank Order Correlations Between Job Sample and MASTS Total Scores

	Rho	n
All subjects	.56	36
Subjects under homogeneous conditions. . . .	.61	18
Subjects under counterbalanced conditions . .	.59	24
Counterbalanced subjects receiving alternate forms:		
JS form IIB and MASTS form IA . .	.45	12
JS form IA and MASTS form IIB . .	.65	12

In summary, these correlations indicated a fairly high correlation between job-sample and MASTS total scores for all groups. The most stable of these (N = 36) would lead one to reject the hypothesis of no relationship at a significance level of one percent. The correlations computed from groups having the same problems (N = 12) were more variable with values both higher (.65) and lower (.45). It was impossible to tell from these data whether this variation was due to problem group differences or sampling fluctuations.

Table II

Rank Order Correlations Between Job Sample and MASTS Part Scores from Receiver and Radar Sub-tests

	MASTS Total	MASTS Receiver	MASTS Radar
Total Group (N = 36)			
JS Total Score	.56	.43	.39
JS Receiver Part Score	.56	.21	.58
JS Radar Part Score	.43	.50	.13
Homogeneous Sub-group (N = 18)			
JS Total Score	.61	.63	.34
JS Receiver Part Score	.74	.56	.68
JS Radar Part Score	.45	.55	.15
Counterbalanced Sub-group (N = 24)			
JS Total Score	.59	.37	.42
JS Receiver Part Score	.57	.21	.52
JS Radar Part Score	.36	.38	.13

Correlations among part scores also varied, and it is not possible to tell which differences represent true differences. However, most of the correlations are moderately high and positive. Job-sample receiver items appeared to correlate consistently more highly with MASTS total scores than did job-sample radar problems, and MASTS radar problems appeared to correlate more highly with job-sample receiver items than they did with job-sample radar items. In fact, the lowest correlations obtained were between the MASTS radar items and the job-sample radar items. This was due in part to a very small range of scores in the radar sub-tests.

Another basis for comparing the two test formats was the difference in the mean number of correct solutions and median solution times. It will be noted from Table III that the job-sample test yielded a significantly greater average number of solutions than did the MASTS test, and for the homogeneous group of subjects (n = 18) the job-sample test gave a significantly longer median time required for solution. Of these, the former comparison (between number of solutions) was more meaningful in this context. The MASTS test would be expected to take less time because the time consumption per move was less. The difference in apparent significance of solution time results for the two groups (counterbalanced, n = 24, and homogeneous, n = 18) was attributed to the presence of administrative variables in the counterbalanced group and their absence in the homogeneous group.

Table III

Differences Between Job Sample and MASTS Tests in Terms of Mean Number of Solutions and Means of Individual Median Solution Times

	Job Sample	MASTS	Diff.	σ Diff.	n	t
Number correct solutions						
Heterogeneous group	7.96	6.75	1.21	.353	24	3.42**
Homogeneous group	8.17	6.94	1.23	.417	18	2.93**
Solution times - minutes						
Heterogeneous group	15.40	14.64	.76	.870	24	.87
Homogeneous group	15.22	13.24	1.98	.802	18	2.47*

* Significant at .05 level
** Significant at .01 level

2. The Modified MASTS Test. The modified form of the symbolic test was introduced to check upon the effect of the form in which the information was provided to the subject. The MASTS test was modified by giving verbal information at test points rather than actual readings. For example, words like "high" or "low" took the place of numbers expressing voltages, ohms, etc. (see previous section).

Correlations between the modified MASTS test and the job-sample and original MASTS tests are given in Table IV. In interpreting these results it is important to keep in mind that the modified MASTS test contained only six receiver items, whereas the original MASTS had six receiver and six radar items. This reduced the range of scores, with a consequent effect upon correlations. The correlations between job-sample total scores and modified MASTS total scores were uniformly lower than those between job-sample and original MASTS scores. However, the amount of difference was small and could be due entirely to the factors mentioned above - and not to intrinsic differences between the original MASTS and the modified MASTS.

The conclusion which appeared most appropriate here was that no clear-cut difference between the two MASTS tests was reflected by the correlational analysis.

3. Summary: Homogeneous Subject Group. Table IV contains the correlations between job-sample, MASTS, and modified MASTS scores for four different scoring procedures. The group on which these values were computed was the "homogeneous subject group," all of whom took the same tests and the same problem groups in the same order. It will be noted that the various scoring procedures yielded comparable results and

the correlations were similar to those in Tables I and II.

Table IV

Rank Order Correlations Between Job Sample, MASTS, and Modified MASTS Scores for Various Scoring Procedures*
N = 18

Test and Scoring Procedure	MASTS Total	MASTS Receiver	MASTS Radar	Modified MASTS
Job Sample Total				
Number solved	.60	.55	.44	.49
Median time	.77	.76	.57	.85
Adjusted cut-off	.67	.74	.42	.60
Combined score	.61	.63	.34	.57
Job Sample Receiver				
Number solved	.71	.55	.66	.68
Median time	.58	.52	.65	.64
Adjusted cut-off	.71	.64	.63	.63
Combined score	.74	.56	.68	.75
Job Sample Radar				
Number solved	.44	.50	.25	.31
Median time	.53	.66	.25	.35
Adjusted cut-off	.37	.54	.10	.35
Combined score	.45	.55	.15	.32
Modified MASTS				
Number solved	.70	.54	.58	
Median time	.72	.69	.58	
Adjusted cut-off	.67	.60	.51	
Combined score	.79	.66	.55	

* Number solved: number of problems solved within respective cut-off times.

Median time: median solution times per subject per test within cut-offs.

Adjusted cut-off: number of problems solved within the median solution times for each problem group.

Combined score: using number solved to rank the subjects and median time to resolve tied scores.

B. Comparison of Job Sample and MASTS Tests With Reference Measures

1. Electronics Reference Tests. The job-sample and MASTS tests were constructed on the assumption that more of the true variation in trouble shooting behavior could be captured in their "realistic"

formats than was possible with more conventional achievement tests of the paper-and-pencil variety. To check this assumption, three paper-and-pencil tests (described earlier) were administered. The three tests represented different subject matters: ER-1 covered knowledge of electronic theory; ER-2 dealt with generalized trouble shooting problems; and ER-3 used problems from the Philco gear as the basis for multiple-choice type test items.

The correlations among the electronic reference tests and the job-sample and MASTS tests are given in Table V.

Table V

Rank Order Correlations Between Performance (Job Sample and MASTS) Test Scores and Scores on Three Electronics Reference Tests (ER-1, ER-2, ER-3)
N = 36

	ER-1	ER-2	ER-3	Combined (Total) ER Score
Job Sample Test				
Total Scores	.62	.70	.64	.69
Receiver Part Scores	.61	.76	.54	.68
Radar Part Scores	.52	.45	.60	.56
MASTS Test				
Total Scores	.55	.55	.46	.56
Receiver Part Scores	.50	.35	.34	.40
Radar Part Scores	.26	.36	.27	.32
Modified Test Scores	.43	.45	.28	.38

Further study would be necessary to determine whether these substantial correlations were due to common subject matter underlying the various formats or to other common variables not necessarily part of electronics trouble shooting skills. It is probable that these results with paper-and-pencil tests would not apply to electronics achievement tests in general. The many possibilities for different paper-and-pencil formats for representing electronics trouble shooting problems have not yet been widely explored or objectively evaluated.

2. Ability Reference Tests. The correlations of scores on the job-sample and MASTS tests with the various ability reference tests are given in Table VI. All were statistically insignificant. The small sample affords little basis for interpreting the obtained differences among coefficients. However, it is probable that the job-sample and MASTS tests are factorially quite complex. They may sample many sources of variation besides those accounted for by the reference tests.

Table VI

Rank Order Correlations Between Performance Tests (Job Sample and MASTS) and Seven Printed Reference Tests
N = 36

	Job Sample Total	MASTS Total	Modified MASTS
Spatial Visualization	.29	.09	.01
Problem Solving	.24	.14	-.07
Verbal Comprehension	.18	.29	-.16
Circle Reasoning	.10	.07	-.15
Match Test	.23	.28	-.04
Brick Uses: Ideational Fluency	-.02	-.04	.22
Brick Uses: Spontaneous Flexibility	-.10	.14	-.21
Logical Reasoning	.16	.24	.18

3. Supervisor's Performance Ratings. The various measures of electronics performance were related to estimates of general trouble shooting ability of the subjects, by a rating obtained from the job supervisor (usually the electronics material officer) of each man.

A fifteen point scale was used with verbal anchors at the extremes and the center. The form used is in Table D in the appendix. It was possible to obtain ratings on thirty of the thirty-six subjects.

The correlations of ratings with scores on the experimental measures are given in Table VII. With the exception of the MASTS test scores, the results were quite in agreement with what would be expected in terms of the intercorrelations of the tests. Because the MASTS results appeared to be atypical, a comparison in terms of significance of the relationship between the ratings and the job-sample and the MASTS tests was made. This was done by converting both sets of data into 2 x 2 contingency tables and computing a chi square test of independence.

Table VII

Rank Order Correlations Between Performance Tests and Supervisors' Ratings
N = 30

	Job Sample Total	MASTS Total	Electronics Ref. Tests	Modified MASTS
Ratings	.50	.21	.46	.52

On the basis of this test one would discard the hypothesis of "independence" between job-sample scores and ratings at the 2% level of significance; whereas the same hypothesis with reference to MASTS scores and ratings would be discarded at the 10% level. It would thus appear safe to conclude there was a significant relation between superiors' ratings and job-sample performance but not between ratings and MASTS scores. This latter result is at variance with the higher relationship between the ratings, the electronics reference tests, and the modified MASTS test.

C. Analysis of Test Administration and Problem Variables

It will be recalled from the earlier discussion of the experimental design that a compromise was made between two objectives: (1) to systematically vary order and problem group variables to determine their effect on job-sample and MASTS scores; (2) to maintain homogeneous administrative conditions as a basis for estimating true correlations. The effects of the administration variables and some of the internal characteristics of the tests will be considered in this section.

1. Test Order. Because the tasks presented to the subjects by the job-sample and MASTS tests were similar, it was predicted that the order in which the tests were taken would influence the scores on each. The job-sample test used equipment which probably was more familiar to the men than was the MASTS test format. Therefore, it was predicted that the MASTS test would profit more from being given second than would the job-sample test. The counterbalanced design provided for each test to be given first and each to be given second an equal number of times, to control this order variable. It is apparent from Table VIII that the order in which the tests were administered did have a significant influence on the test scores. The job-sample test had a significantly greater number of solutions and a shorter median solution time when given first than when given second. The MASTS test yielded a greater (not significant) number of solutions and a significantly shorter median solution time when given second than when given first.

2. Problem Group Differences. Through the use of the counterbalanced design it was possible to administer two complete sets of problems in all orders. The sets of receiver items were labeled I and II

Table VIII

Differences in Mean Numbers of Solutions and Means of Individual Median Solution Times for Two Orders of Test Administration
N = 24

	Administration Order First	Administration Order Second	Diff.	σ Diff.	t
Number correct solutions					
Job Sample	8.83	7.08	1.75	.79	2.21*
MASTS	6.17	7.33	1.16	.75	1.56
Means of Median Solution Times					
Job Sample	15.62	23.54	7.92	3.80	2.08*
MASTS	17.62	11.65	5.98	1.88	3.17**

* Significant at .05 level
**Significant at .01 level

and the radar items A and B. A comparison of the mean number of solutions for these two sets of problems is given in Table IX, and a similar comparison of solution times in Table X. It is evident from both sets

Table IX

Comparison of the Mean Number of Correct Solutions for Different Problem Groups
(N for each sub-group is 12)

Test	Problem Group		Diff.	σ Diff.	t*
	Radar A	Radar B			
MASTS	2.50	3.58	1.08	.461	2.34
Job Sample	3.00	4.00	1.00	.508	1.97
	Receiver I	Receiver II			
MASTS	4.08	3.33	.75	.475	1.58
Job Sample	4.75	4.17	.58	.458	1.27

*Significance levels: 5% t = 2.07
(22 d.f.) 1% t = 2.82

of data that problem groups A and B (radar problems) differed, whereas groups I and II (receiver problems) did not. In the future, use of these problems would profit from a study of the radar problem groups to account for the differences, and to remove factors producing inequality if it were desired to use the groups as alternate or equivalent tests.

Table X

Differences in Solution Times for Different Problem Groups
Based on Means of Individual Median Solution Times
(N for each sub-group is 12)

Test	Problem Group		Diff.	$\sigma_{Diff.}$	t
	Radar				
	A	B			
MASTS	18.25	12.58	5.67	1.40	4.05**
Job Sample	29.58	19.25	10.33	3.18	3.25**
	Receiver				
	I	II			
MASTS	10.62	13.21	2.59	2.07	1.25
Job Sample	15.25	16.88	1.63	3.53	.46

**Significant at .01 level

3. Effect of Order Within Problem Groups. In the counter-balanced design, the order in which individual problems within a particular problem group were administered to the subjects was varied systematically from subject to subject. The purpose of this was to control the effects of warm-up, fatigue, frustration, etc., and to provide some degree of test security. A graph was drawn of the solution times over all problems to show the influence of sequence position. See Figure 1, and comparable data for number of solutions in Figure 2. There is considerable evidence for sequence effects on both variables. Performance

generally was poor on the first problems tried; improved, and sometimes returned to a lower level after four or five problems.

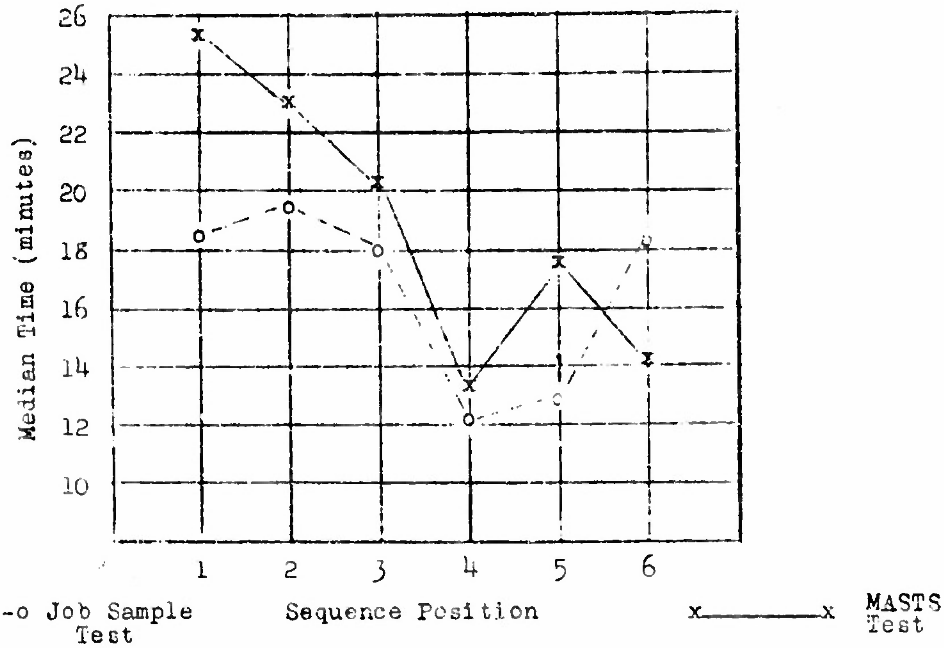


Fig. 1. Median solution times per problem for the Job Sample and MASTS Tests as a function of the sequence position of the individual problems. N = 24

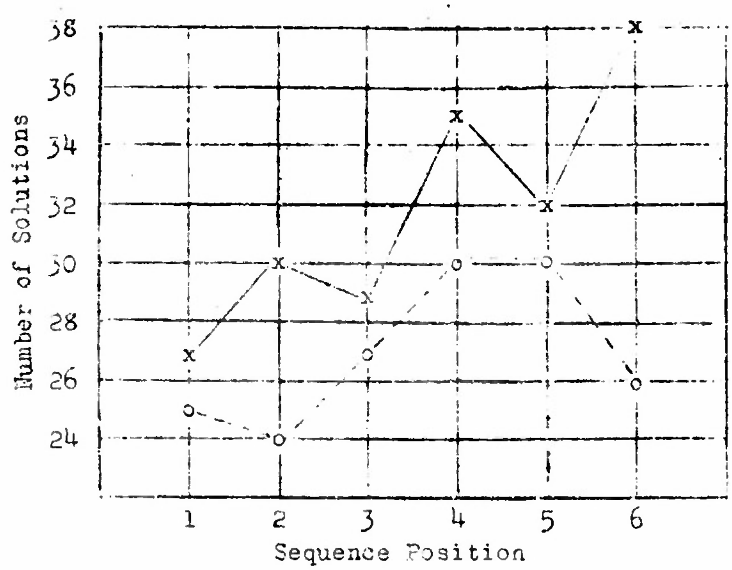


Fig. 2. Number of correct solutions of Job Sample and MASTS problems for different problem sequence positions. N = 24

4. Internal Characteristics of the Tests. The preliminary administration of the job-sample and MASTS tests yielded information for evaluating the tests' internal characteristics - particularly for selecting the most effective problems, eliminating the poor ones, and matching problems on difficulty level. Because the preliminary findings were favorable to the continued use of such tests, an extensive revision of the MASTS test has been undertaken. Therefore, the bulk of the data on the internal properties of these tests will be presented in a later report describing the revised measures.

One comparison which is of interest in this context is the correlation between sub-tests or part scores on the two trouble shooting tests. The results are shown in Table XI.

Table XI

Rank Order Correlations Between Receiver and Radar Scores on the Job Sample and MASTS Tests (For the Homogeneous Group, N = 18)

Variables	Rho
Job Sample: Receiver vs. Radar	.53
MASTS: Receiver vs. Radar	.30

This low correlation for the MASTS test (like those in Table IV) can be attributed in large part to the fact that the variability in each half of the test (6 problems) was very low (most subjects getting from 3 to 5 correct).

In an attempt to estimate the internal consistency reliability of the job-sample and MASTS measures a rank order correlation coefficient was computed between the number of correct solutions among odd-even halves of the individual tests. These results are shown in Table XII.

Table XII

Rank Order Correlations Between Scores Derived From Odd and Even Halves of the Job Sample and MASTS Tests (Number of correct solutions with ties resolved by solutions times; Homogeneous Group, N = 18)

Test	Rho*
Job Sample	.47
MASTS	.50

*Corrected by Spearman Brown formula

It should be noted in interpreting these correlations that the division of these tests into odd and even halves drastically curtails the potential range of scores. Each "half" consists of only three problems.

V. SUMMARY AND CONCLUSIONS

This study was concerned with the development of a symbolic representation of certain aspects of the electronics trouble shooting task, the MASTS Test, and with the relation of the scores obtained from this instrument to other, more conventional measures. Among these were a job-sample equipment test, electronics reference tests, ability reference tests, and supervisor ratings.

The extremely long testing time required per subject for the two trouble shooting tests precluded their administration to the number of subjects originally planned, which would have been more satisfactory for correlational analyses as well as for other comparative analyses.

However, the results of the study were encouraging with respect to the MASTS test. Significant correlations were obtained between the MASTS test and its job-sample counterpart.

Besides the results reported here, the study yielded exploratory tryout and preliminary test construction data on the three major classes of electronics trouble shooting measures involved. These are being used currently in the revision of the MASTS test.

* * * * * * * * * *

APPENDIX

TABLE A

Tabulation of ET Samples by Ships

Ship	No. of ETs in Final Sample
DD1	2
DD2	2*
DD3	4*
DD4	2*
DD5	5*
DD6	5*
DD7	3
DD8	2
CA1	9
CV1	2
	36

*Starred samples indicate that all the ETs aboard that ship served as subjects; in other ships, complete sampling could not be achieved because of various operational conditions such as sailing dates, leaves, training programs, etc.

TABLE B

Subject Data

Rate	N	Naval ET Experience in Months			Electronics Schools			
					Naval			
		0-12	13-24	25 & over	A	B	C	Civilian
ET/SN	7	2	4	1	6	1	1	
ET/3	18	3	6	7*	17	0	5	
ET/2	10	0	4	6	10	1	5	
ET/1	1	0	0	1	1	0	0	
TOTAL	36	5	14	15	34	2	11	

*Experience data was not available for two ET/3 subjects.

TABLE C

Outline of the Experimental Design: Test and Problem Orders

JOB SAMPLE I A

	Rec I							Rad A					
	1	2	3	4	5	6		1	2	3	4	5	6
1	A	B	C	D	E	F	1	S	T	U	V	W	X
2	B	D	A	F	C	E	2	T	V	S	X	U	W
3	C	A	D	E	F	B	3	U	S	V	W	X	T
4	D	E	F	B	A	C	4	V	W	X	T	S	U
5	E	F	B	C	D	A	5	W	X	T	U	V	S
6	F	C	E	A	B	D	6	X	U	W	S	T	V

MASTS II B

	Rec II							Rad B					
	1	2	3	4	5	6		1	2	3	4	5	6
1	G	H	I	J	K	L	1	Y	Z	AA	BB	CC	DD
2	H	J	G	L	I	K	2	Z	BB	Y	DD	AA	CC
3	I	G	J	K	L	H	3	AA	Y	BB	CC	DD	Z
4	J	K	L	H	G	I	4	BB	CC	DD	Z	Y	AA
5	K	L	H	I	J	G	5	CC	DD	Z	AA	BB	Y
6	L	I	K	G	H	J	6	DD	AA	CC	Y	Z	BB

MASTS II B

	Rec II							Rad B					
	1	2	3	4	5	6		1	2	3	4	5	6
7	G	H	I	J	K	L	7	Y	Z	AA	BB	CC	DD
8	H	J	G	L	I	K	8	Z	BB	Y	DD	AA	CC
9	I	G	J	K	L	H	9	AA	Y	BB	CC	DD	Z
10	J	K	L	H	G	I	10	BB	CC	DD	Z	Y	AA
11	K	L	H	I	J	G	11	CC	DD	Z	AA	BB	Y
12	L	I	K	G	H	J	12	DD	AA	CC	Y	Z	BB

JOB SAMPLE I A

	Rec I							Rad A					
	1	2	3	4	5	6		1	2	3	4	5	6
7	A	B	C	D	E	F	7	S	T	U	V	W	X
8	B	D	A	F	C	E	8	T	V	S	X	U	W
9	C	A	D	E	F	B	9	U	S	V	W	X	T
10	D	E	F	B	A	C	10	V	W	X	T	S	U
11	E	F	B	C	D	A	11	W	X	T	U	V	S
12	F	C	E	A	B	D	12	X	U	W	S	T	V

JOB SAMPLE II B

	Rec II							Rad B					
	1	2	3	4	5	6		1	2	3	4	5	6
13	G	H	I	J	K	L	13	Y	Z	AA	BB	CC	DD
14	H	J	G	L	I	K	14	Z	BB	Y	DD	AA	CC
15	I	G	J	K	L	H	15	AA	Y	BB	CC	DD	Z
16	J	K	L	H	G	I	16	BB	CC	DD	Z	Y	AA
17	K	L	H	I	J	G	17	CC	DD	Z	AA	BB	Y
18	L	I	K	G	H	J	18	DD	AA	CC	Y	Z	BB

MASTS I A

	Rec I							Rad A					
	1	2	3	4	5	6		1	2	3	4	5	6
13	A	B	C	D	E	F	13	S	T	U	V	W	X
14	B	D	A	F	C	E	14	T	V	S	X	U	W
15	C	A	D	E	F	B	15	U	S	V	W	X	T
16	D	E	F	B	A	C	16	V	W	X	T	S	U
17	E	F	B	C	D	A	17	W	X	T	U	V	S
18	F	C	E	A	B	D	18	X	U	W	S	T	V

MASTS I A

	Rec I							Rad A					
	1	2	3	4	5	6		1	2	3	4	5	6
19	A	B	C	D	E	F	19	S	T	U	V	W	X
20	B	D	A	F	C	E	20	T	V	S	X	U	W
21	C	A	D	E	F	B	21	U	S	V	W	X	T
22	D	E	F	B	A	C	22	V	W	X	T	S	U
23	E	F	B	C	D	A	23	W	X	T	U	V	S
24	F	C	E	A	B	D	24	X	U	W	S	T	V

JOB SAMPLE II B

	Rec II							Rad B					
	1	2	3	4	5	6		1	2	3	4	5	6
19	G	H	I	J	K	L	19	Y	Z	AA	BB	CC	DD
20	H	J	G	L	I	K	20	Z	BB	Y	DD	AA	CC
21	I	G	J	K	L	H	21	AA	Y	BB	CC	DD	Z
22	J	K	L	H	G	I	22	BB	CC	DD	Z	Y	AA
23	K	L	H	I	J	G	23	CC	DD	Z	AA	BB	Y
24	L	I	K	G	H	J	24	DD	AA	CC	Y	Z	BB

TABLE D

Supervisor's Rating Scale Form

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

WORST	AVERAGE	BEST
Seldom or never succeeds in finding the cause of a mal-function by himself.	More often than not succeeds in locating the cause of a malfunction, but is slower and has to make more checks than the better man.	The man they send for in a crisis, when the gear has to be back on the air immediately, or when every-one else has failed to find an especially difficult trouble.
Unable to interpret symptoms correctly.	Can interpret symptoms, but may not be able to utilize the information in them to the maximum. Generally can quickly isolate the trouble to a major circuit of the gear.	Has almost a "sixth sense" for getting the maximum from symptoms.
Unable to isolate the trouble to a major circuit of the gear.		Isolates the trouble quickly, often by-passing checks other men would need to make.
Uses test instruments in-effectively and may damage them.	Uses test instruments effectively, but does not completely understand their limitations and advantages.	May get into a blind alley, but corrects himself quickly.
May go back to the same blind alley over and over again.	Usually can correct himself when in a blind alley, but sometimes becomes baffled	Can get the maximum information from test instruments in unusual or difficult situations.
Is apt to make mistakes en-dangering himself or the gear.	Understands the gear well enough to work on it without supervision.	Seldom is baffled by a gear failure.

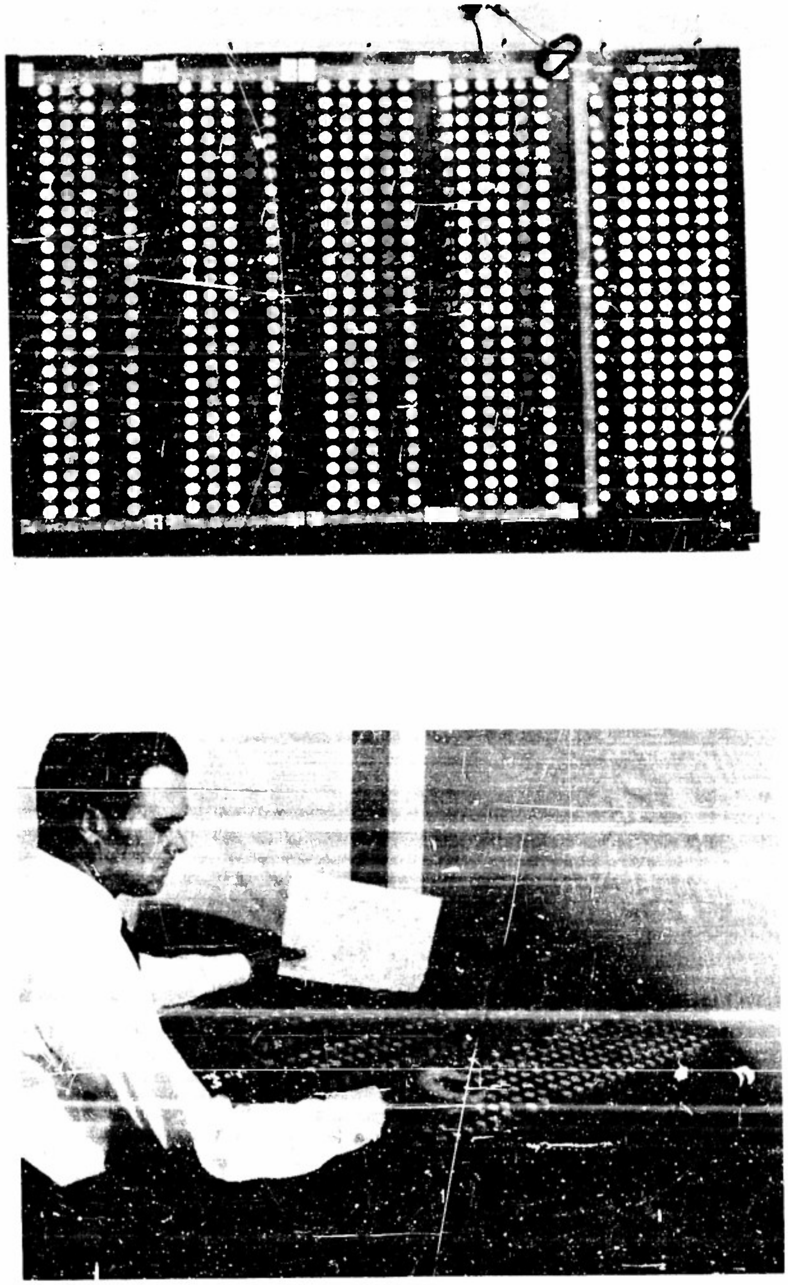


PLATE I. PHOTOGRAPHS SHOWING THE STRUCTURAL FEATURES AND THE USE OF THE MASTS TEST.

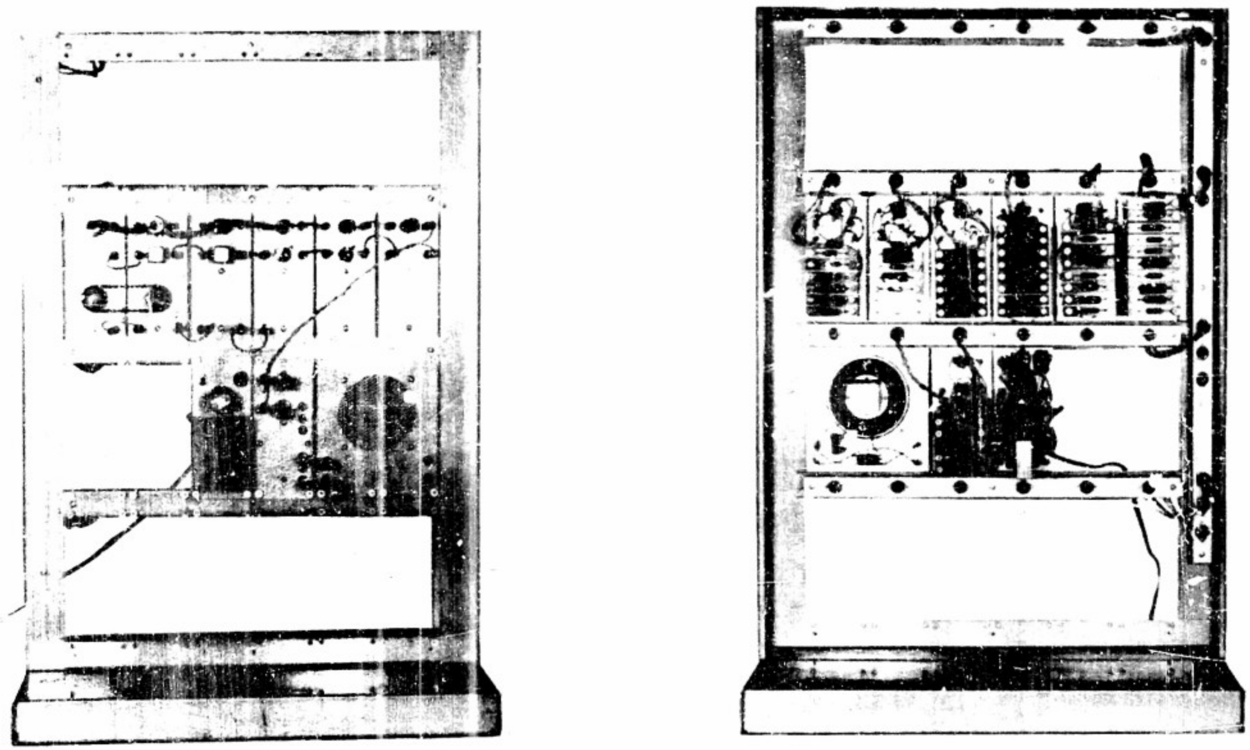
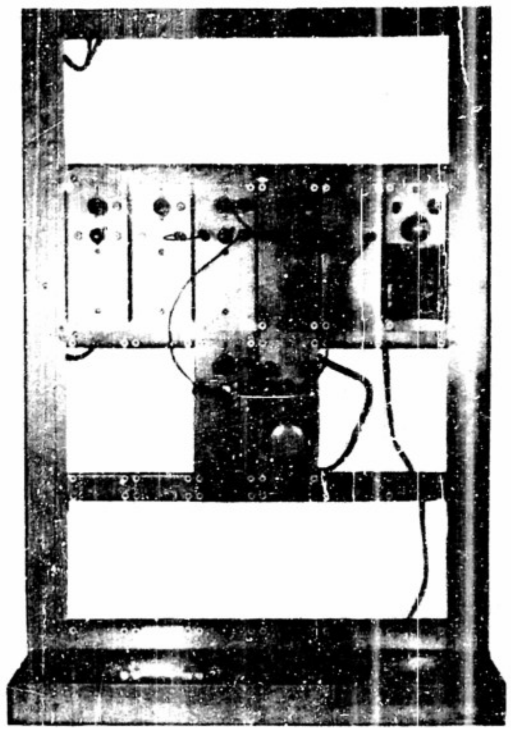


PLATE 2. PHOTOGRAPHS OF THE PHILCO ELECTRONICS TRAINING SET
A. SUPERHETERODYNE RADIO RECEIVER.



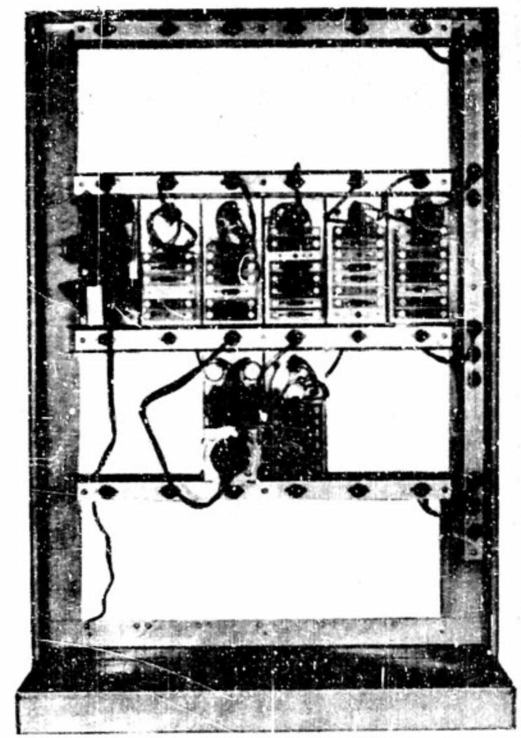
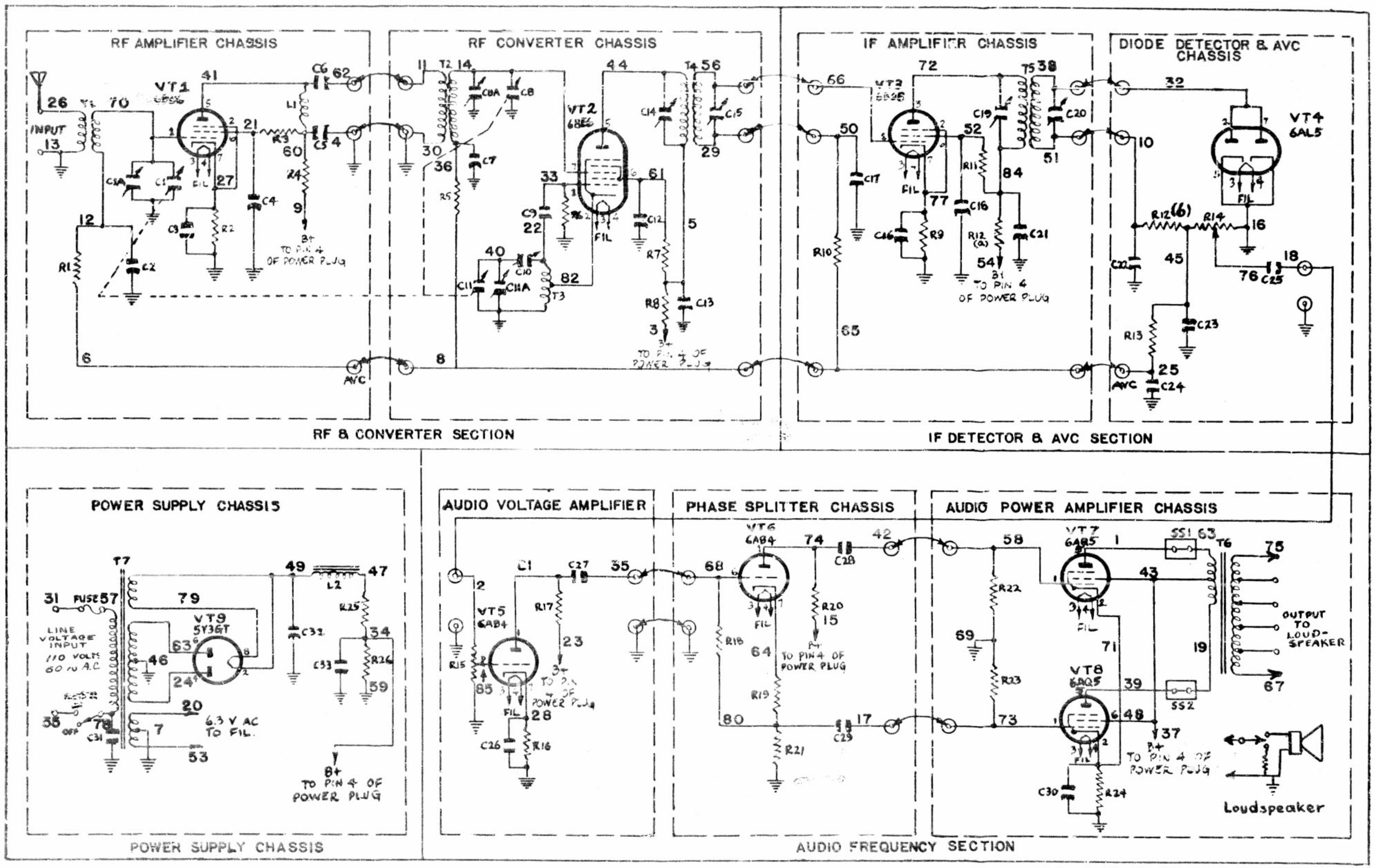
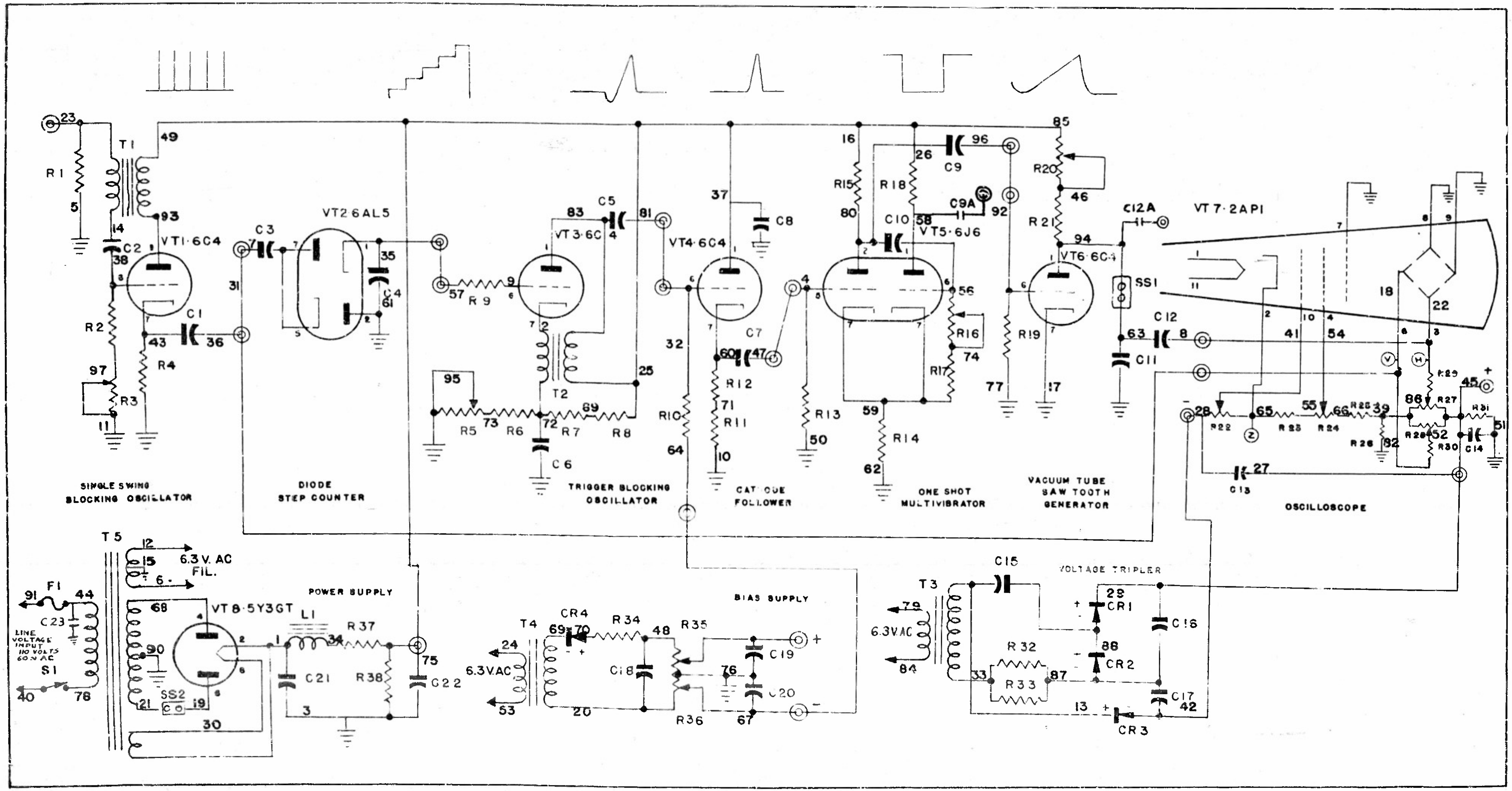


PLATE 2 PHOTOGRAPHS OF THE PHILCO ELECTRONICS TRAINING SET.
B. SIMPLIFIED RADAR SYSTEM.



BASIC RADIO RECEIVER CIRCUIT DIAGRAM.



BASIC RADAR SWEEP GENERATOR CIRCUIT DIAGRAM.